A Study of Support System for Traffic Operating Condition Audit on Expressways

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Abstract

This research has been studied to construct support system for systematic approach of traffic operating condition audit (TOCA) to solve the serious traffic congestion lasting for more than 10 years on freeways. The support system for TOCA includes four major parts, such as decision methodology for congestion management, dynamic traffic assignment technique, traffic analysis software, and congestion management handbook.

This research has been performed according to prearranged scheme and the contents are follows: review of existing congestion index and microscopic traffic simulation model, development of the overall traffic condition index, dynamic O/D estimation, system design of traffic analysis computer program, doing an example of traffic condition audit, and so forth. In recent periods, ex (Ex (Korea Expressway Corporation)) has been under strong pressure to reduce traffic congestion on expressways. Therefore, this project focused on development of support system to help decision maker's policy-making and intended to play the role as a useful tool in future congestion management.

1. INTRODUCTION

(1) Background

Expressway has been base of rapid economic growth of our country, on the other hand congestion on expressway has been severe and enlarged because of increase of traffic demand in recent. In 2007, the length of congested section on expressway was 292km, which was 9.3% of total length of 3,132km. Enlargement of capacity such like lane increasement and road construction has been used to remove congestion. However, to enlarge capacity requires long term period because planning, design and construction process is needed. Thus long lasting of congestion situation is unavoidable after congestion occurrence. Therefore, establishment of quick congestion management alternatives is required to improve existing congestion condition and to prevent added congestion.

This is a follow-up study to a series of studies on the development of highway traffic condition evaluation methods. This study aims to demonstrate the need to introduce a traffic flow evaluation system in order to manage traffic jams systematically and to develop ways to solve related problems. To that end, this study specifies the concept of a traffic condition evaluation system and develops various methods and ways to do so, and finally, systemizes those methods for adoption in real terms. Hence, this study aims at developing a specific, systematic, and fast way to develop a traffic condition evaluation system in order to manage possible traffic jams on highways.

(2) Objective

The objective of this research is to make the concept of Traffic Operating Condition Audit (TOCA) more concrete, and to develop various techniques and methodologies to support TOCA. That is to say, the objective of this research can be said to develop support system for TOCA to manage congestion on expressway.

2. Methodology

In this research, an index for monitoring of traffic operating condition is developed and a methodology to analyze traffic condition is developed. Also, a decision-making methodology which enables decision makers to choose right traffic management alternative on each congestion condition is developed and traffic analysis programme to evaluate the effect of each alternative is developed. In addition, congestion management handbook including definition of congestion, congestion measuring method, classification of congestion, congestion management technique on each congestion section, method to find a robust alternative, and congestion management process is provided.

3. TRAFFIC OPERATING CONDITIONS AUDIT

Traffic Operation Condition Audit (TOCA) is defined as the process of comparing the many alternatives and methods on which to focus in order to understand the reasons for traffic jams and the methods of easing them. This evaluation process of TOCA is categorized into two systems; the prior evaluation to deal with possible traffic jams and the diagnosis of the reasons as to why these traffic jams occur.

In order to carry out a traffic conditions evaluation, we should select the range of the area to be evaluated and should collect the track records for the previous traffic conditions in that area. After collecting the required data, we should conduct studies on the ground while analyzing previously-collected data. Road geometric design, the current traffic conditions, the type of the traffic jams, the points where traffic jams occur, how long the traffic jams continue, and other questions are included in the research and analyses. After those processes, we should estimate the future traffic volume of the selected area in order to build up traffic management methods to prevent possible traffic jams before they occur. To that end, we select the areas that are currently suffering from, or will be suffering from, traffic jams. At the same time, we figure out the reason for those traffic jams and the influences they exert. In terms of the road geometric design and the characteristics of the traffic conditions, we find out the root cause of the traffic jam and analyze the traffic conditions of the road. In order to establish methods of preventing traffic jams from the start and in order to manage traffic jams that have occurred on the highway, we bring out different measures to solve the problems caused by the excessive demand of the road, decreased road capacity due to traffic conflicts, and the failure of the road management system. As a result, we set up measures to secure an appropriate road capacity by preventing traffic conflicts and managing the traffic system more effectively while conducting an evaluation of the management systems of each local government.

4. SUPPORT SYSTEM FOR TOCA

In order to evaluate traffic conditions, we should figure out the root cause of traffic jams, find out the solutions, compare the alternatives, and evaluate the effectiveness of the adopted measures. In each step, we should develop tailored methods and connect them with each other. However, previous studies have only focused on developing and introducing alternatives to ease traffic jams. Thus, we have failed to figure out the exact cause of the traffic jams and to monitor how traffic jams change. At the same time, we have failed to establish a reasonable decision-making process to select the best alternatives based on the priorities, the feasibility, and the effectiveness of each policy and alternative. In order to support the evaluation of traffic conditions in a faster, more accurate and effective manner, this study sets up 4 objectives, which are the key elements of the traffic conditions evaluation support system. Four major contents are as follows;

First, traffic operating condition monitoring index

Second, decision-making methodology for congestion management

Third, traffic analysis program

Fourth, congestion management handbook

5. DEVELOPMENT OF A SUPPORT SYSTEM FOR TOCA

(1) Develop a traffic conditions monitoring indicator

Generally, congestion means traffic jams or traffic delays caused by excessive road traffic demand, problems of road design, and car accidents and others. Hence, the time it takes to get to somewhere during a traffic jam or traffic delay minus of the tie it takes during freely flowing traffic is the congestion time.

The existing traffic congestion index is not based on comprehensive data representing all traffic conditions, but is based upon independent data, such as traffic volume, velocity, time, and others. Even though cars run at the same speed, the severity of the traffic congestion and its length of time can vary, but these kinds of aspects are not well reflected in the previous traffic congestion index. In addition, the existing traffic congestion index is only focused on the current status of the road and there is no standard by which to judge which level of traffic flow is appropriate. Therefore it is hard to set a norm defining the appropriate level of traffic flow.

Thus, this study wants to develop a comprehensive traffic indicator which shows the traffic flow level objectively.

(2) Development of a comprehensive traffic conditions index

The Traffic Conditions Index is defined as an index which measures the traffic circumstances and evaluates them comprehensively. Also, it is the index that shows the traffic status of a certain area objectively. Unlike existing traffic congestion indicators, the TCI focuses on 3 qualities of service; the

mobility (how long does it takes to get somewhere?), the accessibility (how easily can you get somewhere?), and the punctuality (can you get to somewhere in time?).

The TCI aims at expressing an exact traffic condition objectively based on the traffic congestion management goal, which is the standard defining traffic congestion. Therefore, it is important to set the standard or the traffic congestion management goal first. Generally, in the Highway Capacity Manual, LOS E means the peak capacity of the road; however the designated speed or designated service level of the road is used as a standard to define the level of highway operation. This study sets the graph with car speed and the designated service level as a standard with which to manage a traffic congestion and compares the traffic conditions as well as the characteristics of LOS C, D, and E. Finally, it develops a TCI based on LOS D as a standard by which to manage traffic congestion.

(3) Development of the 1st model

TCI takes the density of the road as the main variable to reflect mobility and accessibility simultaneously. The TCI index is based on the difference between the designated density of the road and the traffic density.

$$1stTCI = \frac{DesignDensity}{MeasuredDensity}$$

However, traffic density is hard to calculate arithmetically, so we calculate the traffic density of a certain area based on a formula that includes traffic volume, velocity, and traffic density.

(4) Development of the 2nd model

A more correct and realistic traffic conditions index

When we divide the designated density against the traffic density to define the traffic conditions, we cannot fully consider an area which is not sensitive to a change of traffic speed or which is already under traffic congestion conditions. In order to resolve this problem, we take the 'traveling vehicle speed' into consideration when calculating the traffic conditions. In addition, we use the concept of 'designated speed' to compare the TCI of a certain area with that of other areas. By doing so, we can show the traffic congestion conditions more accurately and compare the TCI of one area with another area.

The division of traffic conditions

In the first model, the range of the index showing smooth traffic conditions is very wide, but that of normal traffic conditions and traffic congestion is too narrow to be changed sensitively according to the road conditions. This means that the traffic conditions index is not sensitive to a change in the road conditions, so the drivers and managers of the traffic systems are not able to be aware of slight changes in the traffic conditions. Therefore, in the second model, we have adjusted the range of the traffic conditions index in each category based on the real traffic conditions.

These characteristics of TCI show that TCI is quite different from other existing indices. Table 1 shows the equation of TCI calculation and the criteria for traffic operating condition. As shown in Table 1, traffic operating condition is divided as three categories of good, fair and poor.

Table 1. Criteria for traffic operating condition

Condition	Criteria	TCI
Good	70≤ TCI ≤100	$70 + (x - 920) \times \frac{30}{(\max - 920)}$
Fair	50≤ TCI <70	$50 + (x - 543) \times \frac{20}{(920 - 543)}$
Poor	0< TCI <50	$x \times \frac{50}{(543 - 0)}$

$$x = \frac{DesignDensity}{MeasuredDensity} \times \frac{MeasuredSpeed}{DesignSpeed} \times 1000$$

Feasibility study

In order to carry out a feasibility study on the TCI, we collected VDS data from the area between Osan IC and Seoul TG on the Gyeongbu highway and the area between Bibong IC and Jonan JC (387.1 ~ 403.3 km (25.2 km)) from October 15, 2007 to October 21, 2007. The n we were able to calculate the TCI and analyze the exact traffic conditions.

Figure 1 shows the comparison between TCI and other indices (volume, speed, TTI) for traffic operating condition on Kyeongbu Expressway (Osan - Seoul). In Figure 1, TCI presents the traffic operating condition as three categories with different other indices. Thus, it might be possible to guess that TCI is more realistic than other indices.

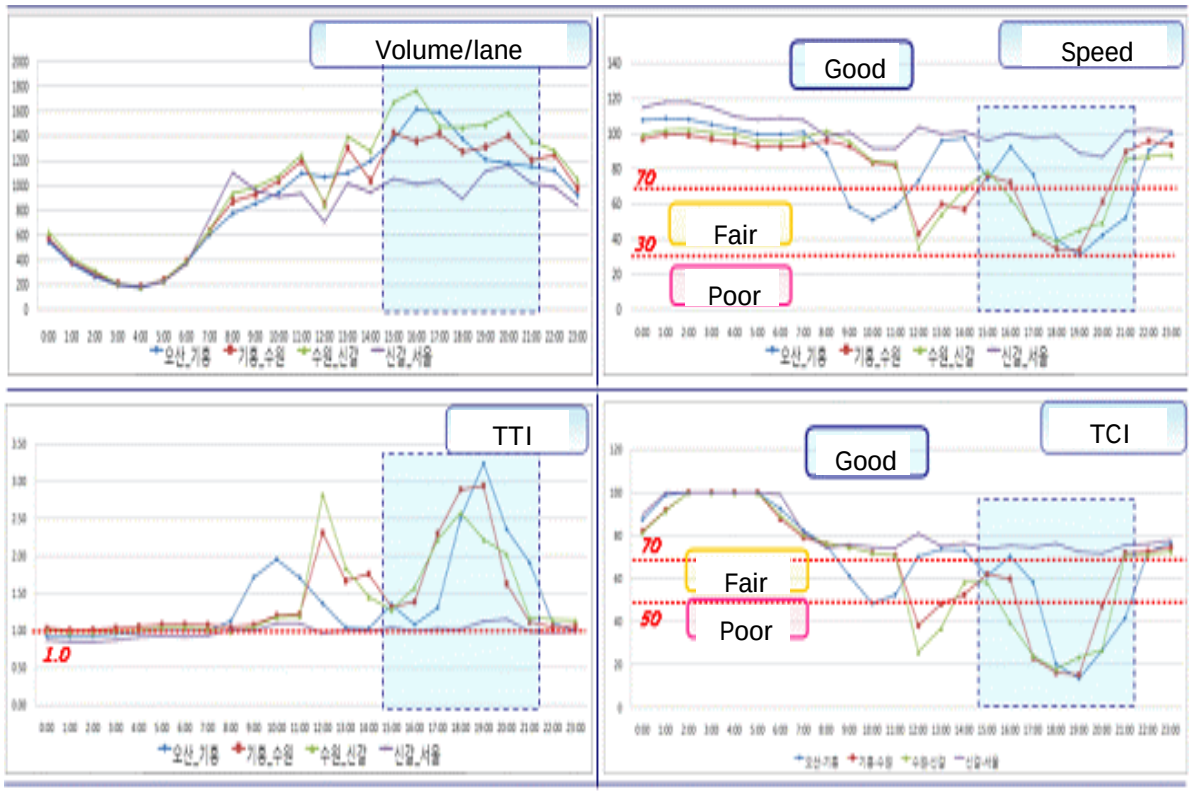

Figure 1. Comparison between TCI and other indices

According to the results, the TTI only showed the level of traffic congestion based on the current vehicle travel speed compared to the freely flowing speed. Thus it failed to reflect the real traffic conditions exactly because there is no value standard with which to divide smooth, normal, and heavy traffic conditions. In addition, it defines traffic congestion when the vehicle travel speed is slower than 30 km/h, while the speed between 30 to 50 km/h is not considered to be in the status of traffic congestion. Thus, it failed to reflect reality accurately.

However, the TCI can show the exact traffic conditions more clearly than the TTI because it has a standard by which to define traffic congestion and traffic service quality. For example, an area between Suwon and Shingal was considered to be a congested area in the previous studies. The TCI showed a similar result to reality but the value of the TTI failed to reflect this.

6. Decision-Making Methodology for Congestion Management

Evaluation on the effect of alternatives is important to select a robust alternative among various congestion management alternatives. Additionally, development of decision-making methodology considering the feasibility and the priority of policy is required. In this research, a new methodology integrating existing measurable and unmeasurable method was developed.

This research reinforced existing measurable method through adaptation of traffic volume and vehicle ratio to calculate more accurate benefit. Moreover, in this research, classification of short-term and long-term alternatives was established. On the other hand, in unmeasurable method, AHP technique was adapted to analyze the priority, feasibility and necessity of policy.

Final decision-making for congestion management is determined by considering the results of both methods

Decision-making process for congestion management is composed of monitoring, decision-making and historic data saving stage.

7. Traffic Analysis Programme

Traffic analysis programme is comprised of data input module (road geometric condition, traffic demand, and so forth), traffic analysis module, traffic demand estimation module, decision-making module. Figure 2 shows the concept of traffic analysis programme.

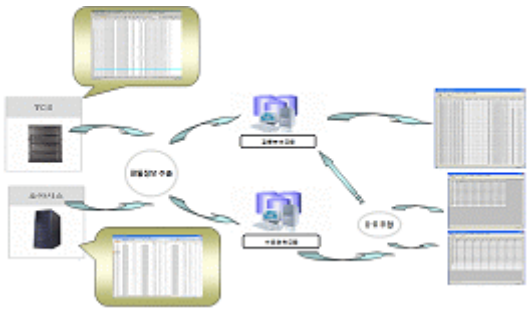

Figure 2. Concept of traffic analysis programme

As shown in Figure 2, raw data is obtained from TCS and FTMS and effective data such like O/D, traffic volume in each time interval (slice) as input data to analysis is derived from algorithm developed in this research. In Figure 3, the analysis flow of traffic analysis programme is presented.

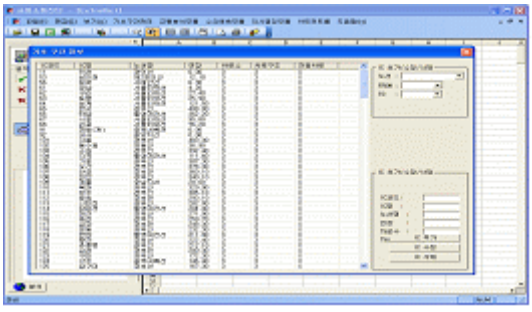

Figure 3. Example of data input

Figure 4 is the example of congestion analysis result. In Figure 4, it is possible to know that where the queue occur and to where the effect of congestion reach. And it is also possible to see that when the congestion happens and disappear. In addition, traffic analysis programme has the function to compare the results between both alternatives.

Figure 5 shows the summarized report. In summarized report, comparison of effect between both alternatives is provided.

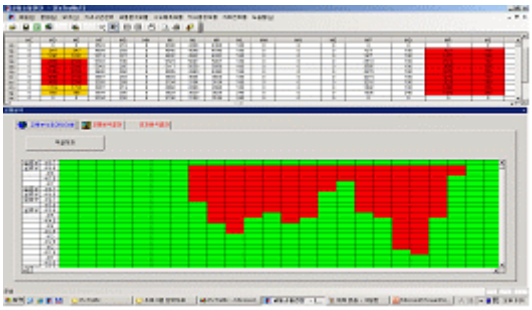

Figure 4. Congestion analysis results in time-space diagram

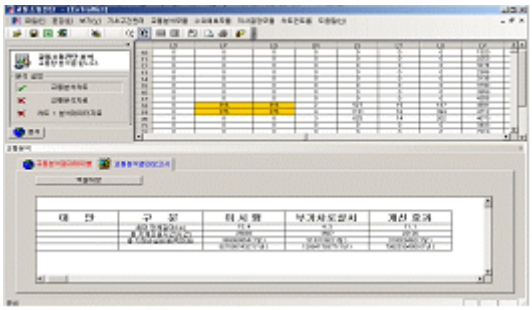

Figure 5. Summary - comparison of effect between both alternatives

8. Congestion Management Handbook

In this research, congestion management handbook is provided. The goal of the handbook is to give some guidelines to traffic managers and thereby, it might be expected that to perform successful traffic management is easy and possible.

Figure 6. Congestion management handbook

9. Conclusions and future studies

This study was carried out to establish a support system for traffic conditions evaluation. We have spent about 10 years researching how to define and deal with traffic congestion. Notably, as the Ex (Korea Expressway Corporation) tries to ease traffic congestions on the highways, we want to establish scientific and systematic traffic condition management methods while providing valuable data for working groups and executives to make the appropriate traffic congestion control policies. Therefore, the TCI and traffic congestion management methods are expected to help us to establish traffic congestion management plans by showing changes in traffic conditions on the road and diagnosing the root cause of traffic congestions. In addition, the traffic analysis electronics program will be helpful to anticipate the influence of traffic congestion and future changes in traffic conditions. Also, the program will help us to evaluate many alternatives and find out the best solution to ease traffic congestion. At the same time, it can also be used as basic data for policy development, including the construction, expansion, modification, and improvement of the highways. Lastly, the working level officials in the highway management department can use these data to establish traffic congestion management policies.

This study created an electronic system to evaluate traffic conditions based on the traffic data. However, further studies and system integration efforts are needed to establish real-time traffic conditions evaluation systems in cooperation with the FTMS and Road Plus of the Ex (Korea Expressway Corporation). In addition, this is a basic study to analyze dynamic traffic conditions. Therefore, we need to conduct further studies to anticipate future dynamic traffic demands. In the long term, more traffic analysis models, tailored to the environment of each highway, are needed.

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